Top pair production at a future 27 TeV HE-LHC

Alexander Mitov

Cavendish Laboratory

UNIVERSITY OF CAMBRIDGE

Total cross-section

- ✓ At a 27 TeV HE-LHC the top-pair production cross-section is very large:

σ_{tot} [27 TEV, m_{top}=173.3 GeV] = 3727 $^{+ 119\ (3.2\%)}_{- 179\ (4.8\%)}$ [pb] (in NNLO QCD)

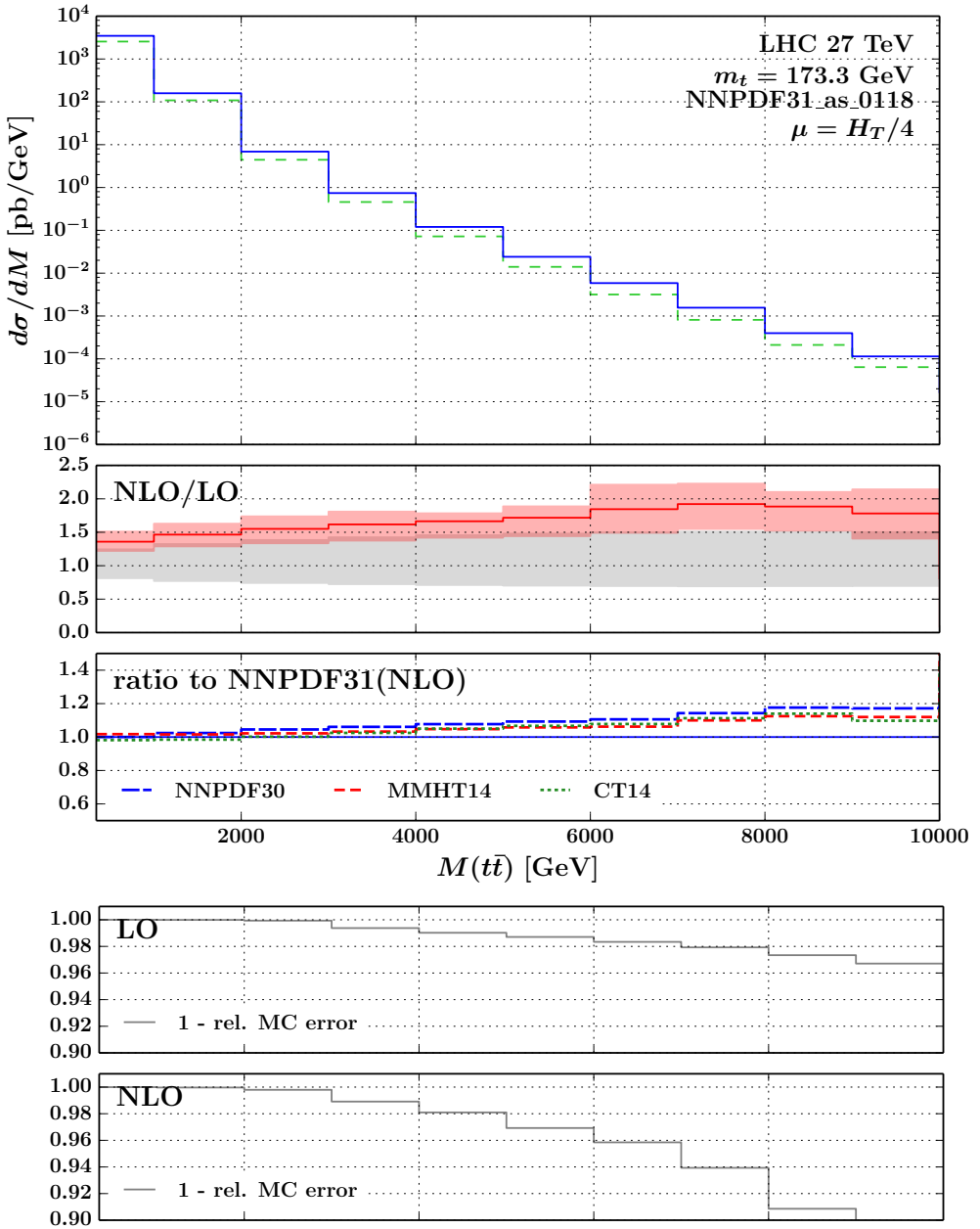
- ✓ This is 4x larger than at LHC 14 TeV

- ✓ Composition of the initial state at 27 TeV:
  - ✓ gg = 92% , qqbar = 6% , qg = 2%

- ✓ Approximately the same composition of the initial state as at 14 TeV:
  - ✓ gg = 90% , qqbar = 9% , qg = 1%

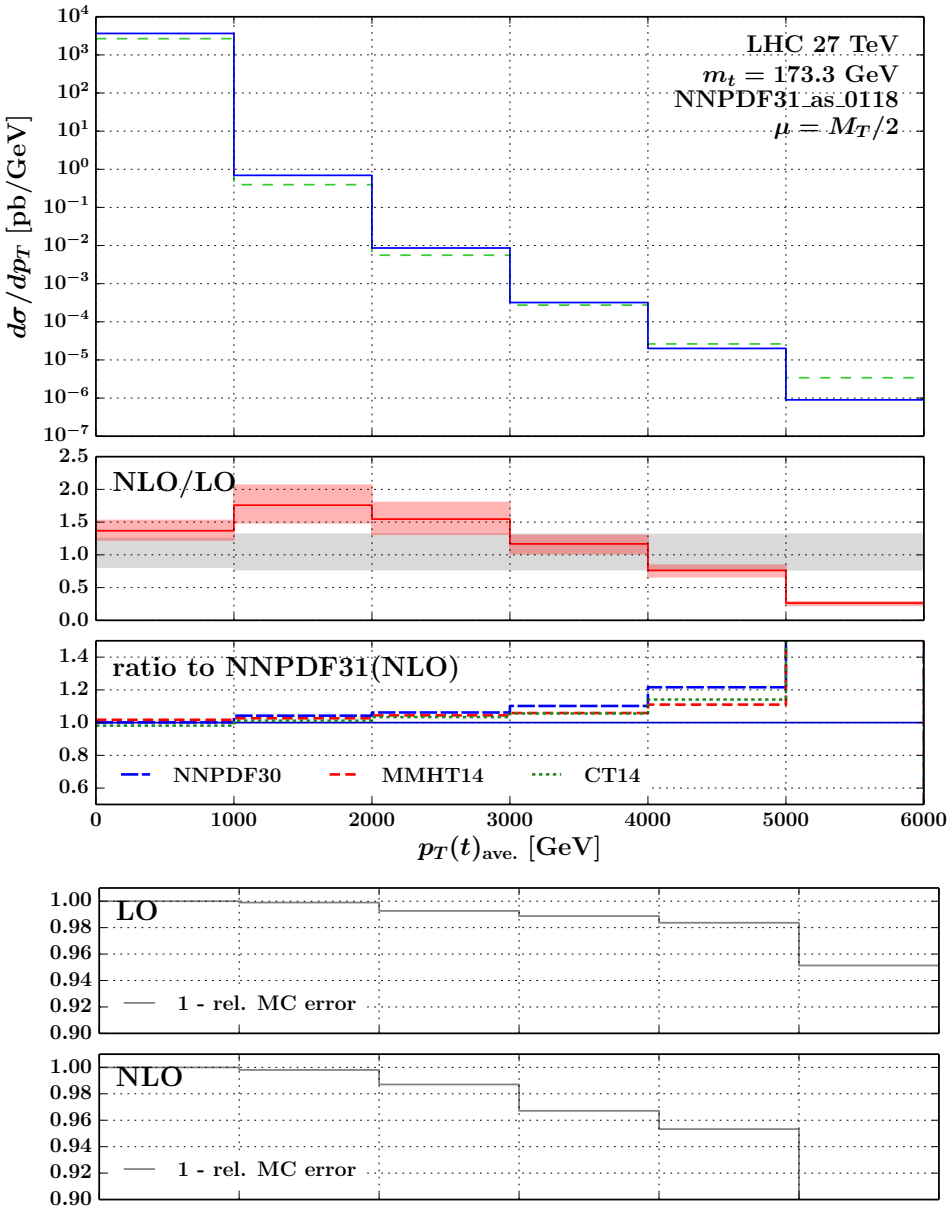
Differential reach in M_{tt}

- ✓ At LHC at 27 TeV very large M_{tt} can be reached
- ✓ Estimates at LO and NLO:
  - ✓ 10% effect in the tails from NNPDF3.1 w/r to older sets
  - ✓ MC error can be handled up to M_{tt}~10TeV
  - ✓ The dynamic scales behave OK (at least) up to 10 TeV
  - ✓ Very modest growth of scale error



Differential reach in P_T

- ✓ At LHC at 27 TeV very large P_T can be reached: up to 6 TeV
- ✓ Estimates at LO and NLO:
  - ✓ Significant difference in the tails from NNPDF3.1 w/r to older sets
  - ✓ MC error can be handled to M_{tt}~6TeV
  - ✓ The dynamic scales behave OK up to (at least) 6 TeV
  - ✓ Scale error is OK



Some novel issues in top production at 27 TeV

Is top massive if P_T is above 3 TeV?

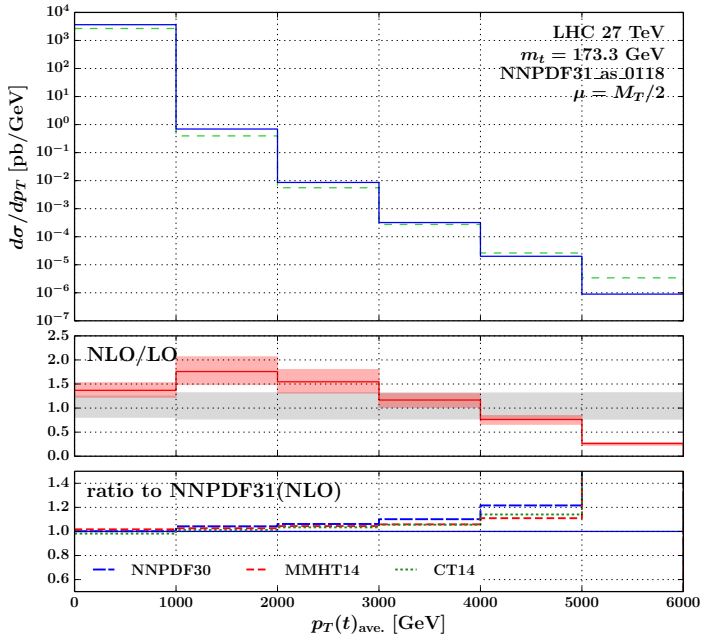
- ✓ 5FS versus 6FS for top production?
- ✓ A new study on heavy flavors and pdfs shows that for factorization scales above 10x the mass a massless scheme is appropriate

  Bertone, Glazov, Mitov, Papanastasiou, Ubiali (to appear)
- ✓ If we take the factorization scale used here: $\mu_F=m_T/2$, we can conclude that above $P_T=3$ TeV the top is massless.

  Czakon, Heymes, Mitov '16
- ✓ To cover P_T as high as 6 TeV one will need:
  - ✓ Top pdf (not a problem – it is purely perturbative)
  - ✓ Well identified tops as studied now are unlikely to be the correct objects to study
    - ✓ Use top jets: can be computed at NNLO with either massive or massless tops. Will be useful in the context of current boosted top analyses.
    - ✓ Calculate with massless identified tops (perturbative fragmentation function). This will be available at NNLO relatively soon; also needed for b-production.

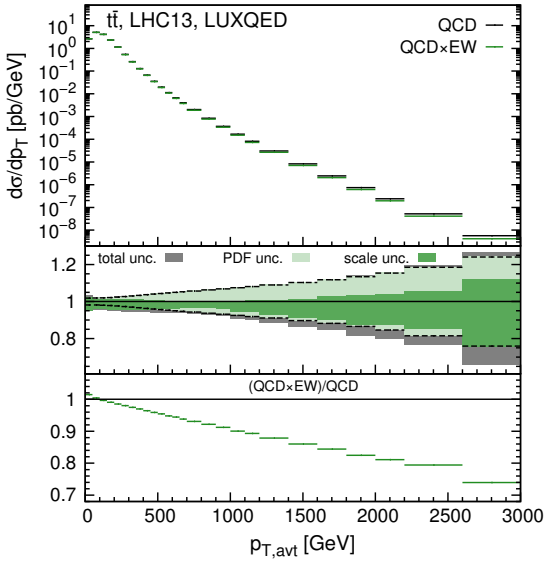
Are pdf's under control at such a large P_T?

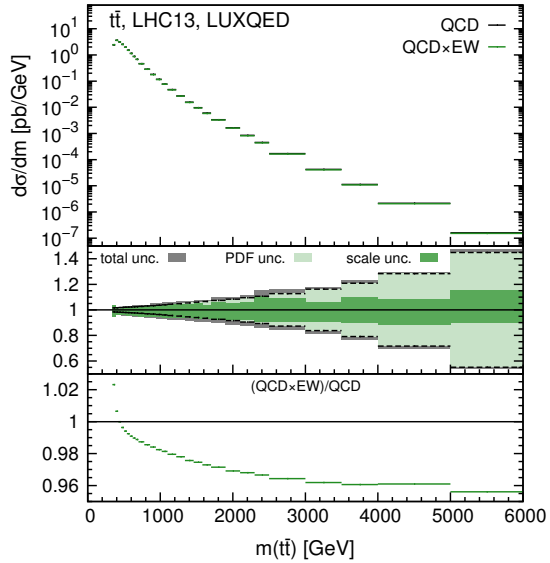
- ✓ Plot to the right indicates new generation of pdfs have different behavior at large PT
- ✓ Recall: new LHC data included in NNPDF3.1, in particular top production at 8 TeV
- ✓ Chances are that by the time HE-LHC starts operations pdfs will be much better than today.

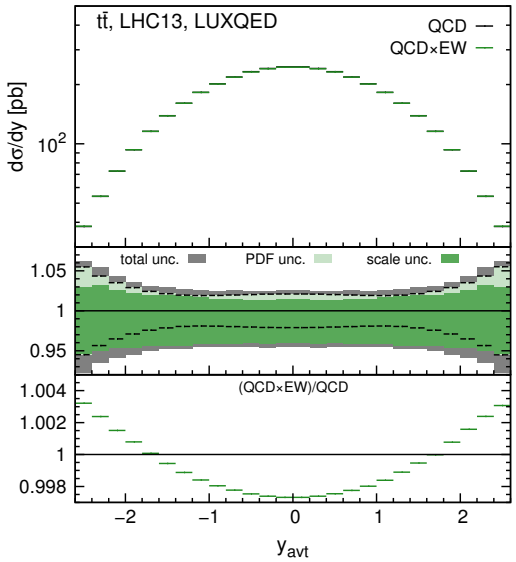


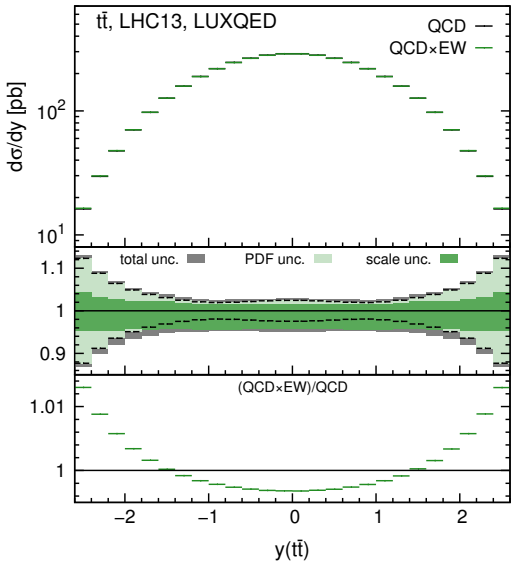
EW corrections

- ✓ From 13 TeV studies one can see that EW corrections in the multi-TeV range are very important
- ✓ They can be computed and their inclusion should not be a challenge









Czakon, Heymes, Mitov, Pagani, Tsinikos, Zaro 2017

Soft-gluon/small mass resummation

- ✓ An important question will be: how reliable our scale choices are for very large P_T?
- ✓ This question will be addressed in time with data, but one would like to have better theoretical arguments beforehand
- ✓ Using resummation is one way to probe the dynamics at such scales.
  - ✓ Ongoing work: Czakon, Ferroglia, Heymes, Mitov, Pecjak, Scott, Wang, Yang (to appear soon)
- ✓ It appears one should be able to give definite conclusions. Please stay tuned!

Conclusions

- At 27 TeV kinematics where the top is effectively massless will be probed in detail
- NNLO accuracy calculations should be able to cover the full kinematic range
- Dedicated definitions for top will be required
  - Top jets
  - Massless identified tops
  - Top-quark pdfs
- Improved pdf sets will be needed at high P_T but this should be possible if one utilizes future HL-LHC data.
- Improvements to pdfs at large-x from lattice QCD might be available by then.
- At present we have sufficient control over EW corrections (which will be very important)
- Reliability of scale choices can be assessed. It appears to be good.
- Additional studies that would be valuable:
  - Decays of tops and scale choices
  - Single top production and its interplay with ttbar